High energy cosmic gamma ray detection with the AMS02 experiment

J.P. Vialle

High Energy Cosmic Gamma Ray detection with the AMS02 Experiment

Jean-Pierre Vialle
LAPP - CNRS/IN2P3 et Université de Savoie
Chemin de Bellevue - BP 110
F-74941 Annecy-le-Vieux Cedex, France
On behalf of the AMS Collaboration

The AMS02 detector, designed for the accurate measurement of charged cosmic ray fluxes, can detect and measure accurately cosmic gamma rays in the GeV to TeV range. Its performances and expected physics results, based on Monte-Carlo simulations, are presented.

1 Introduction

The AMS-02 detector[1] is a large acceptance magnetic spectrometer — 0.5 m^{2}sr — which will be installed in 2008 on the International Space Station, for at least 3 to 5 years. The experiment aims at measuring with high statistics and high precision the cosmic ray fluxes and spectra in the GeV to TeV energy range. AMS will provide a continuous survey of charged cosmic rays fluxes, and the most sensitive search for the existence of anti matter nuclei $\overline{He}$ or $\overline{C}$ with a sensitivity of $10^{-9}/10^{-7}$ and for the origin of non-baryonic dark matter looking at the $\overline{p}$, $\overline{D}$, e^+ and γ spectra. It will also allow to observe and study high energy cosmic γ-ray sources.

The core of the AMS02 detector is an eight planes silicon tracker (TRK), inside a cylindrical superconducting magnet of 0.86 T.m^2 bending power. The resolution of the TRK of 10 μm in the bending plane ensures a momentum resolution better than 2% for rigidities up to 10 GV/c rising to 20% at 1 TV/c. A four layer Time of Flight hodoscope (TOF) with 120ps accuracy determines unambiguously the direction of particles traversing the detector (to reject upward going particles from albedo). The TOF is also used for triggering on charged particles. Above the TOF, a transition radiation detector allows an electron-proton separation close to 10^3 up to 300 GeV/c, while below the lower part of the TOF a Ring Imaging Cerenkov counter allow to measure the velocity β of particles and nuclei with an accuracy of 0.1%. At the bottom of the detector, a 3d imaging electromagnetic calorimeter[2] (ECAL) with an active area of 648×648 mm^2 and 16 radiation lengths in depth gives an electron-proton separation power better than 10^3. It consists of 9 supermodules made of lead/scintillating fibers sandwich and oriented alternatively in x and y direction, giving for each shower 18 samplings in depth and a granularity of 0.5 Moliere radius in the transverse plane. The AMS-02 detector will be rigidly attached to the ISS, pointing to the deep sky near the zenith. Due to the precession of the orbital plane of the ISS with a period of about 71 days, the detector will be able to complete a full sky coverage about 5.3 times per year.

2 γ-ray detection with the AMS-02 detector

Photons can be detected in the AMS experiment either from e^+e^- pair conversion of gamma rays in the material upstream of the first silicon tracker *(conversion mode)* layer[1], or from direct showering in the electromagnetic calorimeter *(single photon mode)*without interacting before. Photons in the conversion mode are directly detected by the standard charged trigger of the experiment. An ECAL stand-alone topological γ-trigger is implemented for the single photon mode which has no charged tracks above the ECAL.

The backgrounds to the γ signals are the dominant cosmic ray components, ie the *protons* and the *electrons*. To get a background-to-signal ratio of the order of a few per cent or below, a background rejection level around $10^5 - 10^6$ must be obtained.

In the *conversion mode*, the event signature is made of two tracks reconstructed in the Tracker originating from a common vertex somewhere upstream of the first tracker layer. The energy resolution is 6% and the angular resolution 0 .02° for a 100 GeV photon. The main sources of background come from p and e^- interacting with the AMS material and producing secondaries, mainly δ-rays. In the *single photon mode*, the event signature is the only presence of electromagnetic energy deposition in the ECAL. The energy resolution is 3% and the angular resolution 1° at 100 GeV, while the main sources of background come from events with charged particles either passing in the gaps of the active tracking volume or entering the ECAL from the sides.

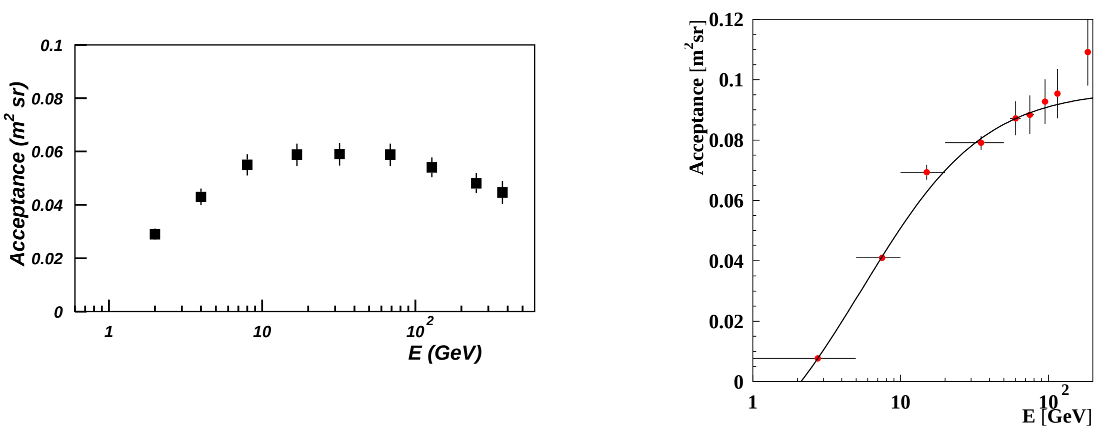

Figure 1: AMS-02 γ-acceptance as a function of energy : *conversion mode* (left) and *single photon mode* (right).

The figure 1 left shows the Tracker acceptance as a function of the γ-ray energy. The e^+e^- pair detection is limited below 5 GeV by the curvature of charged particles and above 200 GeV by the tracker double-hit resolution. From 5 to 200 GeV the detector acceptance is above 0.05 m^2sr, and the proton rejection is about 10^5. The corresponding effective area is 450 cm^2 at

[1]The material in front of the first silicon tracker plane, consisting of the TRD, the first two layers of ToF scintillators, and mechanical supports, represents about 0.25 X_0., giving a probability of conversion of about 20%

the zenith with an opening angle of 46°. On figure 1 right the ECAL acceptance is shown as a function of the γ-ray energy. At 100 GeV, the detector acceptance is 0.097 m^2sr, with a proton rejection of about 4.7×10^6. The corresponding effective area is 3500 cm^2 at the zenith and the opening angle is 23°.

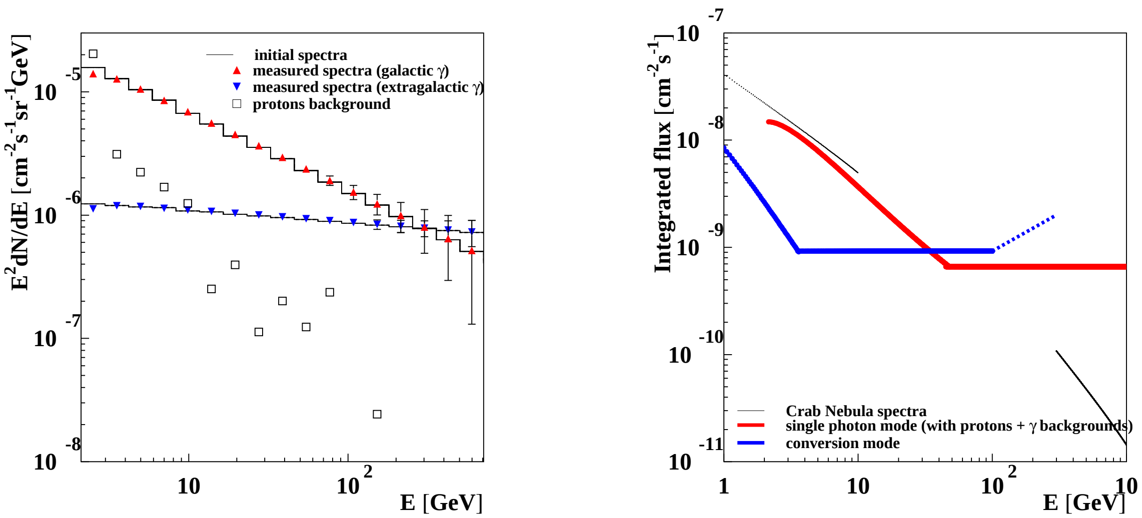

Figure 2: Expected 3-years measurement for *single photon mode* of the diffuse photon spectra (left) and 5σ extragalactic point source sensitivity for both modes with 1-year exposure (right).

3-years measurement of the photon spectra for the galactic and the extragalactic diffuse spectra with AMS-02 *single photon mode* are shown in figure 2 (left). An estimate of a 5σ extragalactic point source sensitivity for one year of exposure in the *conversion mode* and in the *single photon mode*, shows the complementarity between the two modes (fig. 2, right).

3 γ-ray physics potential with the AMS-02 detector [3]

The two main models of γ-emission in pulsars are polar cap and outer gap, depending where the emission by accelerated charged particles takes place[4]. In the unexplored energy region above 10 GeV, the observation of the Vela pulsar by the AMS-02 detector will allow the discrimination between these models with only one year of data taking (fig. 3, left). The AMS-02 detector should be able to observe the Vela pulsar up to TeV energies, making the link with Cerenkov telescopes on ground.

High energy photons can be produced by annihilation of neutralinos in the Galactic Center. The figure 3 (right) shows the prediction with a set of parameters in mSUGRA models[5] such that the mass of the neutralino is larger than 200 GeV and the relic density compatible with WMAP results. The astrophysics term in the predicted γ-flux is larger than 5000, due to a small core radius in the Navarro-Frenk-White profile used. AMS-02 sensitivity to this new physics will build up over the years since the calorimeter, not requiring a magnetic field, is expected to pursue measurements over up to 10 years.

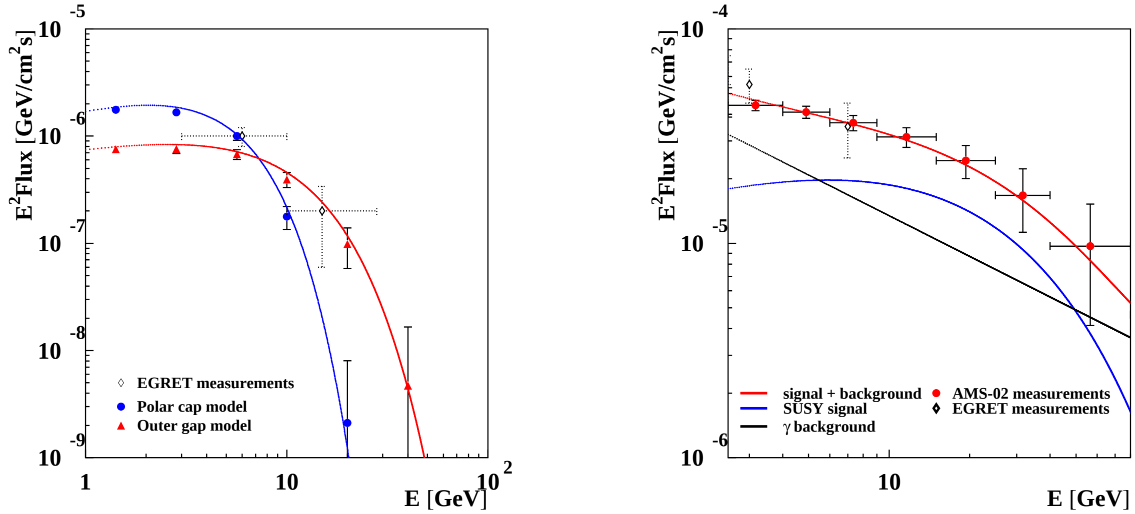

Figure 3: Expected 1-year measurement for the Galactic Center with *single photon mode* (right) and of the photon spectra for the Vela pulsar with both modes (left).

4 Conclusion

The AMS-02 detector on the International Space Station will measure with high statistics and high precision the various cosmic rays, providing important informations on their origin and propagation. The AMS-02 effective area together with its good energy resolution and angular determination offers an useful combination for the investigation of the GeV-TeV γ-ray sources in the sky. This γ-ray physics potential, good for pulsars and dark matter searches, is also promising for Active Galaxy Nuclei and Gamma Ray Bursts studies.

References

[1] AMS Collaboration, M. Aguilar et al., *Phys. Rep.* **366**, 331-405 (2002).

[2] F. Cadoux et al., *Nucl. Phys. (Proc. Suppl.) B* **113**, 159 (2002).

[3] L. Girard, PhD Thesis (University of Savoie), LAPP-T-2004-05, (2004) and proc. of the Moriond conf. (2005)

[4] A.K. Harding, *astro-ph/0012268*.

[5] W. de Boer, M. Herold, C. Sander, V. Zhukov, *hep-ph/0309029*.